SCIENCE EDUCATION FOR STUDENTS WITH SPECIFIC LEARNING AND ATTENTION DISORDERS: AN EVALUATION OF READING STRATEGIES USING EYE-TRACKING TECHNOLOGY

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Abstract

This case study examined how students with learning (dyslexia) and attention deficit process science texts under different instructional design conditions using eye-tracking technology. The aim was to examine the impact of seductive details and visual enhancement elements on reading behaviour and cognitive load. A qualitative case study was conducted with three neurodivergent students and one neurotypical participant (ages 11–14), each exposed to four conditions: plain text, highlighted text, infographic, and decorative image. Eye-tracking data revealed that neurotypical reading was efficient, with short fixations, minimal regressions, and focused attention. In contrast, neurodivergent students exhibited disorganized scanpaths, particularly under conditions involving infographics and decorative images. Highlighted and plain text conditions supported more structured reading, especially for the student with dyslexia. The results suggest that seductive details increase extraneous cognitive load and distract attention in students with cognitive vulnerabilities, whereas signaling via text highlighting may partially support comprehension. These findings highlight the potential of eye-tracking to inform inclusive instructional design and emphasize the importance of minimizing irrelevant visual input in science education materials.
Keywords: *attention-deficit disorder, specific learning disorder, reading difficulties, eye-tracking technology, scanpath comparison*

Introduction

Success in learning builds self-confidence and helps achieve goals. One of the first goals in school is to learn reading, counting, and correct speech (Bellocchi et al., 2013; Church et al., 2023). Reading integrates visual, attentional, and oculomotor processes, not just linguistic ones (Schuett et al., 2008). Already in 1879, ophthalmologist Louis Émile Javal observed eye movements during reading, noting they differed from usual gaze behaviour (Prabha et al., 2019). Since the 1970s, infrared-based eye-tracking (ET) technology has enabled objective analysis of how students process texts and direct attention (Angele & Duñabeitia, 2024; Y. Chen et al., 2023). Nowadays, developing eye-tracking technology (hereafter referred to as ET) offers numerous advantages, primarily due to its non-invasive nature. In contrast to traditional methods of identifying not only cognitive processes but also learning difficulties, ET is more time-efficient and generally reduces stress for participants, thereby potentially minimizing error rates and

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data distortion linked to stress. Besides, traditional questionnaires rely on subjective interpretations of results and are often not adapted to linguistic or cultural diversity. Beyond ET benefits, this method allows participants to engage in research tasks directly on a computer screen with minimal effort and enables the collection of quantitative data that objectively contributes to studies of reading behaviour, attention distribution and identification of learning difficulties (Coenen et al., 2024; Toki, 2024). In recent years, ET has been widely applied in fields such as advertising and communication, particularly for evaluating the effectiveness of marketing strategies (Bauer & Hantel, 2022; Grigaliūnaitė & Pilelienė, 2015), in clinical studies, including those focused on oculomotor changes associated with dementia (Norouzi et al., 2025), neurodegenerative conditions (Marandi & Gazerani, 2019), and reading impairments such as dyslexia (Toki, 2024).

Reading is a cognitively demanding task involving eye movements to gather visual input and extract meaning (Mohammadhasani et al., 2020). It has been discovered that reading skills are heritable and some genes have been found to be associated with reading difficulties (Church et al., 2023). Dyslexia is a learning disorder associated with neurological differences affecting phonological and language processing (Daniutė & Staliūnienė, 2021). People with dyslexia often report oculomotor issues, such as "jumping lines" or blurred text, despite normal vision and average intelligence. These issues impair cognitive processing and affect reading and writing. Early diagnosis is critical due to the brain's plasticity in early age (Bellocchi et al., 2013; Coenen et al., 2024; Toki, 2024).

Attention-deficit/hyperactivity disorder (ADHD) is a chronic neurodevelopmental disorder marked by difficulties in attention and behavior regulation (Lee et al., 2023). Mohammadhasani et al. (2019) recorded that these impairments are also linked to working memory deficits and abnormal eye movements. Eye-tracking may support the diagnosis of comorbid dyslexia in individuals with ADHD (Caldani et al., 2022).

Reading is essential in science education, where texts often include technical language and are supported by graphs, diagrams, and tables (Toki, 2024). As noted by Tosun (2022), learning natural sciences requires higher-order thinking, such as critical thinking and problem-solving. Students have to make interpretations of complex natural phenomena visually presented in schemes. Rapid science discoveries and information updates create challenges even for neurotypical students, and these are amplified for those with special educational needs.

Learning materials now often include design elements like seductive details, images, infographics, and highlighted text. While these can boost engagement and motivation, their impact on learning depends on relevance and cognitive load. Seductive details – interesting but irrelevant – can distract learners and increase extraneous load, especially for those with low prior knowledge (Eitel et al., 2019; Harp & Mayer, 1998; Wesenberg et al., 2025). Though they may spark interest, their effect on retention and application is mixed (Schneider et al., 2019; Stark et al., 2024; Sundararajan & Adesope, 2020; Wang & Adesope, 2016; Wesenberg et al., 2025). In contrast, well-designed infographics and highlights that relate to key content reduce cognitive load and aid comprehension (Çaka & Dursun, 2022; Dogomeo & Aliazas, 2022; Majooni et al., 2018; Ponce et al., 2022; Wu & Liu, 2024). Based on dual coding theory, these elements support learning by combining verbal and visual input, helping build long-term memory (Clark & Paivio, 1991; Mayer, 2024).

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Cognitive Load Theory (CLT) explains how the limits of working memory affect learning (Sweller, 2024). It distinguishes intrinsic, extraneous, and germane load, emphasizing the need to reduce unnecessary load and support meaningful processing (Hanham et al., 2023). Baddeley's (2003) model views working memory as a multi-part system for storing and manipulating information. Cowan (2001) notes its limited capacity, especially relevant for learners with attention or learning difficulties. Clear visuals and infographics can reduce extraneous load and enhance cognitive engagement.

Eye-tracking research builds on the eye–mind hypothesis, which links gaze behavior with cognitive processing (Just & Carpenter, 1980). Fixation duration and saccades often indicate effort or confusion. In multimedia learning, Mayer's theory emphasizes balancing visual and verbal input to optimize learning and reduce overload (Mayer, 2024; Mayer & Moreno, 2003). For students with learning difficulties, success depends on how well materials fit their cognitive capacities. Self-Determination Theory (SDT) adds that autonomy, competence, and relatedness support motivation (Deci & Ryan, 2000). Relevant visual aids can reduce stress and improve engagement, while irrelevant ones may increase cognitive load.

Donmez (2023) reviewed 48 studies on ET in special education, mostly focused on dyslexia and autism. Key learning areas included reading, language, math, communication, motor skills, and navigation. ET was shown to help adapt learning environments based on students' observed behaviors. Chan et al. (2022) found that ET-based training improved memory, reading, and learning speed in students with learning difficulties, including ADHD, compared to regular remediation.

Typical reading scanpaths follow a left-to-right, top-to-bottom pattern (Schuett et al., 2008). Caldani et al. (2022) found that children with dyslexia or ADHD show longer fixations, more saccades, and slower reading compared to neurotypical peers. Key eye-tracking metrics include total reading time, fixation count and duration, and regressions (Luegi et al., 2011). Longer fixation durations are associated with increased information processing, cognitive effort, and engagement, and are typically interpreted as indicators of higher cognitive load (Coskun & Cagiltay, 2022; Ke et al., 2024; Liu & Cui, 2025; Negi & Mitra, 2020). A higher number of fixations may reflect greater learning engagement and sustained attentional focus, suggesting an elevated level of cognitive load (O. Chen et al., 2023; Coskun & Cagiltay, 2022; Ke et al., 2024; Mateja & Borawska, 2024). Longer or wider saccades are indicative of more intensive visual exploration or transitions between areas of interest or sources of information (Coskun & Cagiltay, 2022; Mateja & Borawska, 2024). A higher number of regressions suggests processing difficulties, cognitive confusion, or challenges in decoding textual information (S. Chen, 2024; Donmez, 2023; Toki, 2024).

Luegi et al. (2011) offered an additional measure called *Progression-Path,* measuring forward reading effort in critical regions. However, it has not been tested with neurodivergent students. Nagarajan et al. (2023) found that the chronological sequence of gaze fixation and saccades, called scanpath, can be addressed as a distinguishing tool for identifying good and poor readers. Similarly, Coskun and Cagiltay (2022), Krejtz et al. (2018), and Sáiz-Manzanares et al. (2021) declare that scanpath reflects attention strategies and response timing, offering insights into cognitive processing.

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Research Problem

Students with specific learning and attention disorders, such as dyslexia and ADD or ADHD, often struggle with reading and processing complex scientific texts. However, little is known about how their visual attention and cognitive processing – especially in science education contexts – are influenced by instructional design elements like seductive details: pictures, infographics, and highlighted text areas. This study addresses the gap by using eye-tracking technology to examine how these students visually engage with scientific content and how seductive details affect their reading behaviour and cognitive processing patterns, using eye-tracking technology. Also, this study expands on earlier research analysing heatmaps of a single student with dyslexia (Raudoniūtė, 2025), by examining scanpath patterns of three neurodivergent learners, including the previously studied case.

Research Focus

The study focuses on evaluating how students with specific learning (dyslexia) and attention (ADHD) disorders visually process scientific educational content using eye-tracking technology. It explores the impact of educational design – specifically the presence or absence of additional instructional elements – on their reading behaviours, such as scanpath patterns, fixation durations, and regressions, to better understand possible cognitive load and reading strategies in science education contexts.

Research Aim and Research Questions

The aim of this research was to study how students with specific learning and attention disorders (dyslexia and ADHD) process science education texts using eye-tracking technology, with a particular focus on how seductive details influence their visual attention, reading strategies, and cognitive load. According to this aim, a few research questions were formulated. First is how do students with dyslexia and attention deficits or ADHD differ in their eye-tracking metrics (e.g., fixation duration, regressions, scanpath) when reading scientific texts compared to typical readers? Second, what is the effect of seductive details on the reading behaviour and attention distribution of students with dyslexia and attention disorder or ADHD while engaging with science content with or without additional enhancing instructional elements? The third question is whether an eye-tracking analysis of scanpath provides insight into the educational design needs of students with specific learning difficulties in science education.

Research Methodology

General Background

This study employed a qualitative case study approach to explore how students with specific learning and attention disorders visually engage with scientific texts presented under different instructional enhancement conditions. The case study design was chosen for its strength in capturing in-depth, context-sensitive insights into eye movements and

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cognitive processing during reading. Focusing on three neurodivergent students and one neurotypical student, the research examined their scanpath behaviors as they interacted with science texts containing seductive details, highlighted segments, infographics, or no enhancements. By selecting a real classroom-like setting and integrating eye-tracking data, this methodology allowed for a nuanced understanding of how educational design influences attention allocation and cognitive load among diverse learners.

Sample

This case analysis constitutes a separate part of a broader study that initially focused on neurotypical students. In the original study, a total of 49 students participated; however, three of them reported having special educational needs. As a result, their data were excluded from the main study and instead examined through an individual case study approach. The performance of these three neurodivergent students was compared to the remaining 46 neurotypical participants. A targeted convenience sampling method was used, focusing on students aged 11 to 14 years. The participants were 5th to 8th grade students attending a private general education school in Lithuania. This age group was selected based on Skurvydas et al. (2023), who note that students within this developmental period typically possess sufficient reading and analytical skills, while still actively developing the capacity for self-regulated learning. Moreover, 11–14-year-olds are considered a suitable age group for examining the effects of cognitive load, as their working memory capacity is still maturing and remains sensitive to extraneous information. This developmental sensitivity made it possible to explore how educational material design influences attention and reading patterns. Among the three neurodivergent participants, one 5th-grade student reported a diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder. The second participant, a 7th-grade student, was diagnosed with specific learning disorders (dyslexia). The third, an 8th-grade student, reported both specific learning disorders (reading and writing) and an attention disorder. Written parental consent was obtained in advance via email, following an informational letter outlining the study's purpose and ethical guidelines. Participation was entirely voluntary. All student data were anonymized using participant codes to ensure confidentiality. The study was approved and conducted in accordance with ethical standards for research involving minors.

Instrument and Procedures

The educational content used in the study was adapted from a 6th-grade natural sciences textbook ("Horizontai", Part 2, pp. 62–65, 2024 edition, Šviesa publishing house). It consisted of four brief science texts on adolescent brain development, each modified with a different instructional enhancement:

- an emotionally engaging but irrelevant image (seductive detail),
- highlighted key information,
- an infographic summarizing the key content visually,
- a control text with no additional design elements.

Each text was followed by two comprehension questions: one assessing knowledge and understanding, and the other assessing information application. Both questions were

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directly related to the content displayed on screen. However, in this case study, test results (correct and incorrect answers to the questions) and learning outcomes will not be discussed.

Due to limitations in the RealEye system, each text was presented twice per session – once before each question – leading some participants to skip re-reading during the second exposure, a natural behaviour acknowledged in the analysis.

The eye-tracking platform RealEye was used to monitor participants' gaze paths via computers (laptops), requiring only a web camera and internet access. While the system records various quantitative metrics, this case study focused specifically on the interpretation of scanpath data to understand reading patterns and strategies.

The procedures were conducted in a quiet, well-lit classroom. Laptops with connected mice were prepared, and students were seated individually. The entire session lasted approximately 15 minutes per participant. During this time, the RealEye platform recorded gaze data while participants read and answered questions. No material compensation was offered; however, students were informed that they could later review their personalized gaze recordings if they participated in a follow-up session.

Data Analysis

Although this study employed a qualitative case study approach, the analysis incorporated visual data captured through the RealEye platform (https://www.realeye.io/), which records the gaze behaviour during the reading process. The primary analytical focus was placed on scanpath visualizations, which allowed for a qualitative interpretation of students' attention patterns, reading strategies, and cognitive load.

While no statistical analysis was conducted in the traditional sense, the scanpath inherently contained quantitative indicators embedded within the visualization, such as fixation duration, sequence, and saccade direction. For example, orange dots in the scanpath represent fixations – the points at which the reader's gaze pauses. The size of each dot correlates with fixation duration, where smaller dots indicate brief glances and larger dots show longer visual engagement, typically associated with higher cognitive effort. The sequential numbering of fixations reflects the temporal order of gaze, thus revealing whether the reading was linear, regressive, organised, or chaotic. Lines connecting the dots, known as saccades, show the movement between fixation points, and zigzag or backward saccades (regressions) were interpreted as indicators of re-reading, difficulty integrating information, or information search behaviour.

This interpretive framework enabled the researcher to derive both visual and cognitively meaningful insights from each student's reading behaviour. The analysis compared the visual attention patterns of three neurodivergent students to a neurotypical student across four instructional formats, focusing on how each condition influenced scanpath structure, attention distribution, and reading strategies. This integrated approach provided a rich, process-oriented understanding of reading behaviour in a science education context, without relying on statistical tests or aggregated group comparisons.

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Research Results

E1, E2 and E3 are the abbreviations for the students with learning difficulties (E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder, E2 was diagnosed with specific learning disorders (specifically – dyslexia); E3 was diagnosed both specific learning disorders (reading and writing) and an attention disorder). Letter "T" stands for the case of a neurotypical student to compare the scanpath results.

In Figure 1, all participants viewed a text accompanied by an infographic. E1's scanpath is chaotic and widely dispersed, with small fixation points and long, erratic saccades – indicating re-reading and disorganized attention. E2's scanpath is more structured, with fixations mostly on the text, though zig-zag regressions suggest difficulty following lines, consistent with dyslexia. E3's scanpath is scattered across both text and infographic, showing frequent, non-linear shifts and wide regressions – signs of attention difficulty and trouble selecting relevant content.

In contrast, the neurotypical student's scanpath is linear and efficient, moving left to right with minimal regressions. The text and infographic are clearly segmented, and fixations focus on key sentences. After reading, the question area was scanned, followed by targeted regressions to retrieve specific answers. This pattern reflects low cognitive load and well-developed reading comprehension.

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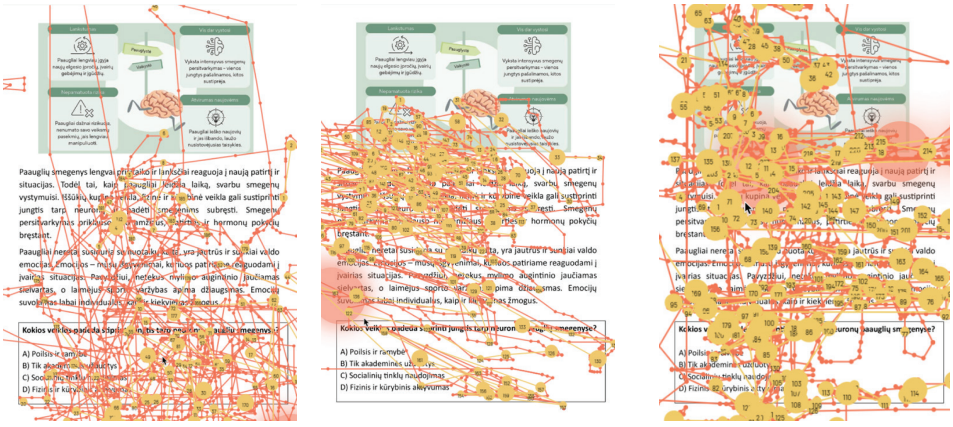
Figure 1

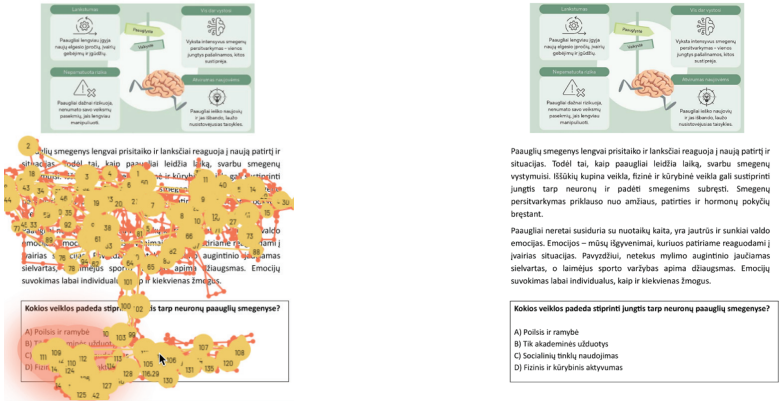
Infographic With Retention (First) Question



E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

E2 was diagnosed with specific learning disorders (dyslexia)

E3 both specific learning disorders (reading and writing) and an attention disorder.



Neurotypical (T)

Example of the exercise

Note. The text provided in the exercise: In the infographic: “Flexibility: adolescents more easily acquire new behavioral habits, abilities, and skills. Still Developing: intensive brain restructuring is taking place – some connections are removed, others are strengthened. Unmeasured Risk: adolescents often take risks without foreseeing the consequences of their actions, making them easier to manipulate. Openness to New Experiences: adolescents seek novelty and test boundaries, often breaking established rules”. Main text: “Teenage brains adapt easily and respond flexibly to new experiences and situations. Therefore, how adolescents spend their time is important for brain development. Activities full of challenges, physical activity, and creative tasks can strengthen the connections between neurons and support brain maturation. Brain restructuring depends on age, experience, and hormonal changes during adolescence. Adolescents often experience mood swings, are sensitive, and have difficulty managing emotions. Emotions are our inner experiences, felt in response to different situations. For example, losing a beloved pet brings grief, while winning a sports competition brings joy. The perception of emotions is highly individual, just like each person.” Question: “Which activities help strengthen the connections between neurons in the adolescent brain?” Answer options: “A) Rest and relaxation, B) Only academic tasks, C) Using social media, D) Physical and creative activity”.

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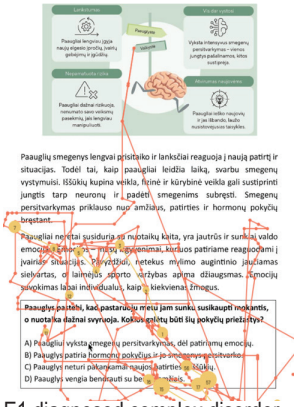
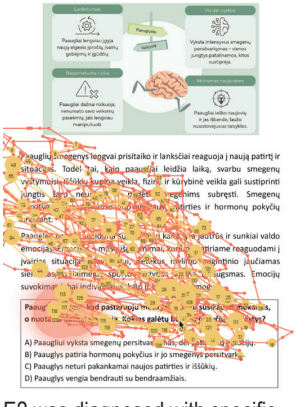
Figure 2

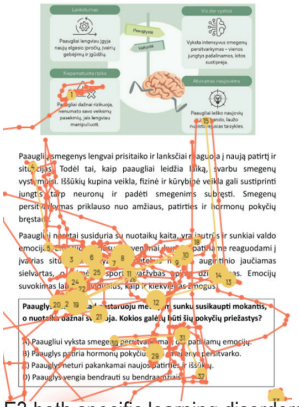
Infographic With Transfer (Second) Question



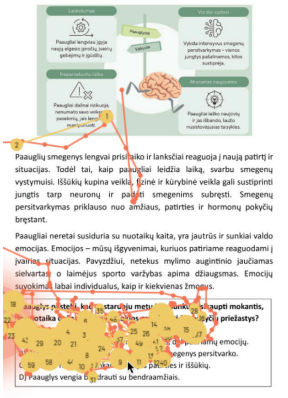
E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder



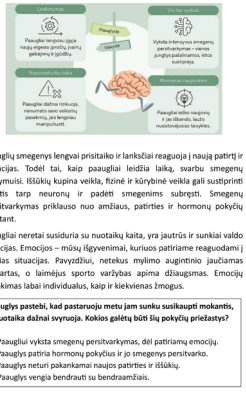
E2 was diagnosed with specific learning disorders (dyslexia)



E3 both specific learning disorders (reading and writing) and an attention disorder.



Neurotypical (T)



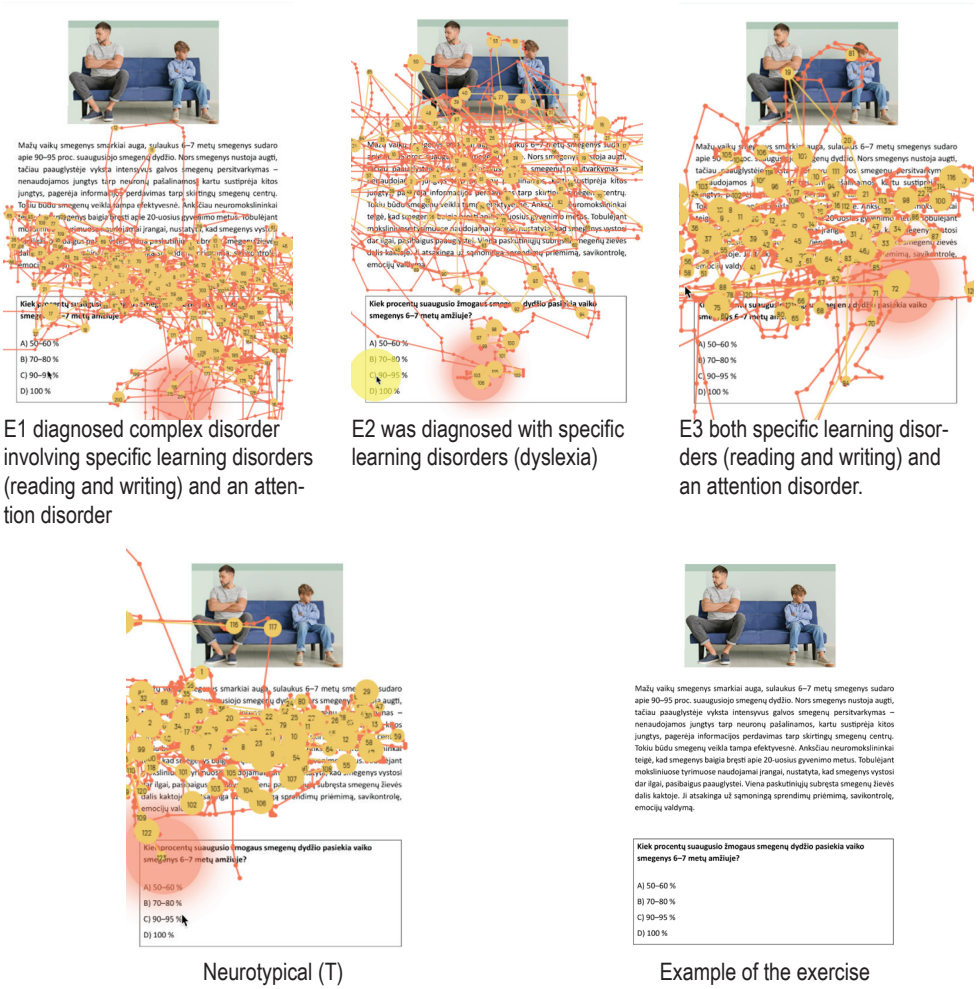
Example of the exercise

Note. The same infographic and text. Only transfer question and answer options have changed: "A teenager notices they have trouble concentrating while studying and experience frequent mood swings. What could be the causes of these changes?A) The adolescent's brain is restructuring, and they are experiencing emotions. B) Hormonal changes and brain restructuring are occurring. C) The adolescent lacks enough new experiences and challenges. D) The adolescent avoids socializing with peers."

Figure 2 presents the scanpath for the same infographic condition but with a different – transfer – question. As noted, although the learning content remains the same as in Figure 1, all three divergent students (E1, E2, and E3) tend to read the text once again, while the neurotypical student only glances at the text passage to make sure it is the same information and never came back later.

Figure 3

Picture With Retention Question



E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

E2 was diagnosed with specific learning disorders (dyslexia)

E3 both specific learning disorders (reading and writing) and an attention disorder.

Neurotypical (T)

Example of the exercise

Note. The text: "Children's brains grow rapidly, and by the age of 6–7, they reach about 90–95% of an adult brain's size. Although the brain stops growing, adolescence involves intense brain reorganization – unused neural connections are eliminated, while others are strengthened, improving information transfer between different brain areas. This makes brain functioning more efficient. Previously, neuroscientists believed that the brain finishes developing around the age of 20. However, new technologies have shown that development continues even after adolescence. One of the last regions to mature is the prefrontal cortex, which is responsible for decision-making, self-control, and emotion regulation." Question and answer options: "What percentage of adult brain size does a child's brain reach by age 6–7?A) 50–60%. B) 70–80%. C) 90–95%. D) 100%"

Figure 3 displays the learning material with an irrelevant (decorative) image at the top and a retention question below the text. E1's scanpath was focused on the lower part of the text and the question area, showing fragmented reading but no visual engagement with the picture. E2's scanpath was widely dispersed and less linear, with multiple fixations on the image – especially the man's and boy's body language and the

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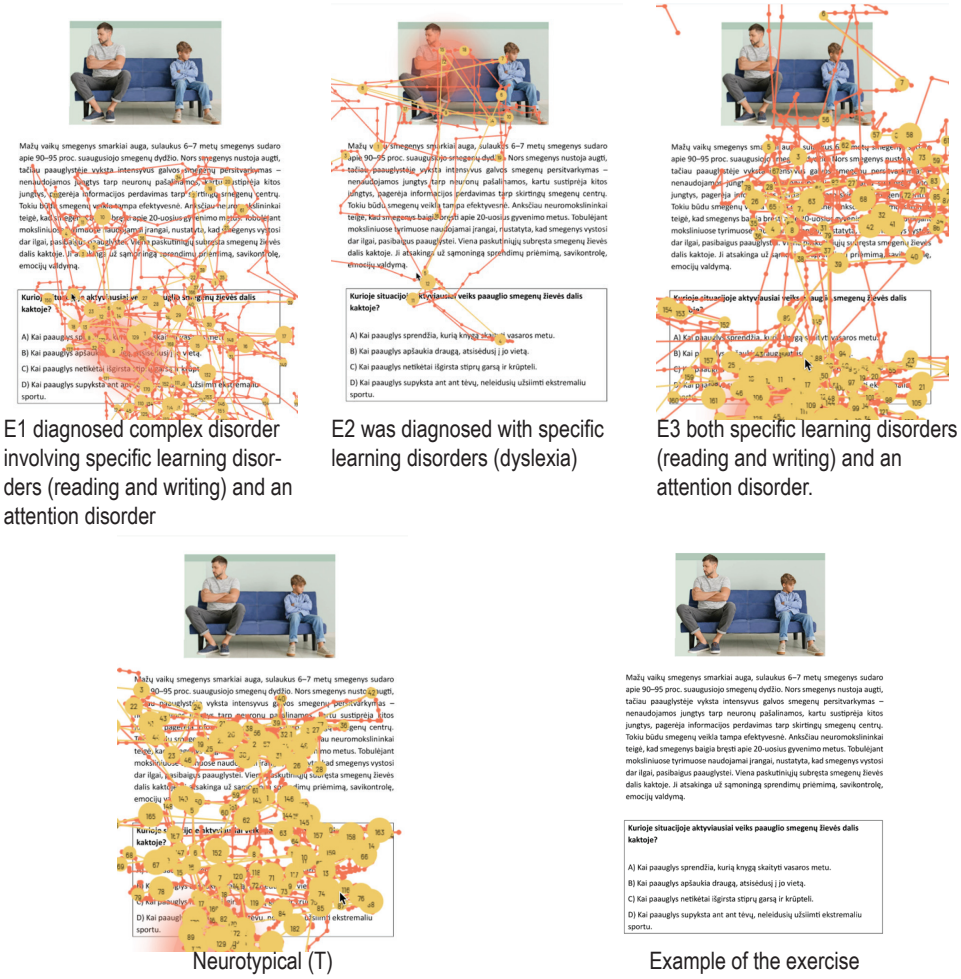
boy's face – indicating distraction. Despite this, E2 accessed the question area directly after reading, without regressions. E3 also fixated on the image midway through the text, particularly on the crossed arms and facial expressions, but showed difficulty sustaining a coherent reading path, as indicated by scattered, non-sequential fixations. In contrast, student T demonstrated an efficient reading strategy: a quick glance at the picture after finishing the text, followed by a direct transition to the question. T's scanpath was linear, left-to-right, with moderate fixation density and minimal regressions.

Figure 4

Picture With Transfer Question



E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

E2 was diagnosed with specific learning disorders (dyslexia)

E3 both specific learning disorders (reading and writing) and an attention disorder.

Neurotypical (T)

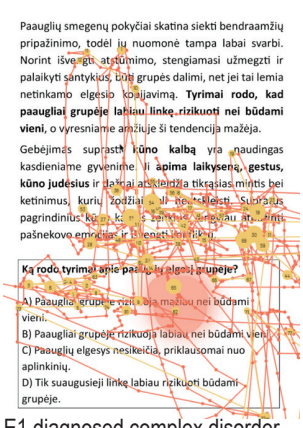
Example of the exercise

Note. Only question and answer options have changed: "In which situation is the prefrontal cortex of an adolescent most active?" Answer options: "A) When a teenager decides which book to read during summer. B) When a teenager yells at a friend who sat in their seat. C) When a teenager flinches after hearing a loud sound. D) When a teenager gets angry at parents for not allowing extreme sports."

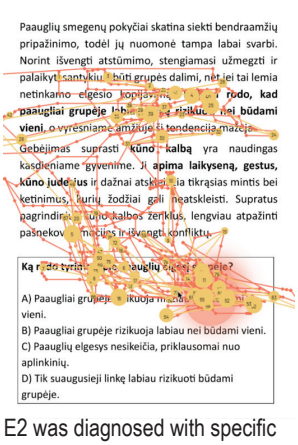
Figure 4 shows the same decorative-image condition but paired with a transfer-type question. E1's scanpath was highly disorganized, with long, erratic saccades shifting non-linearly between the question and text. The image was ignored. E2 began reading the text but quickly moved to the question area. Upon seeing the word "adolescent," E2 fixated on the boy in the image, then switched back and forth between the picture and the text – indicating an attempt to extract meaning from irrelevant content. The main text was largely overlooked. E3's scanpath involved three zones: image, text, and question. Compared to E1 and E2, E3 devoted more time to reading and analysing the question, focusing primarily on the right-hand side of the text and treating the answer options proportionally. Student T showed a structured pattern, re-reading the text and concentrating on the answer options. The image received no attention, suggesting T recognized it as irrelevant. Despite being non-informative, the decorative image drew attention from all three neurodivergent students, demonstrating the seductive details effect in learners with cognitive vulnerabilities.

Figure 5

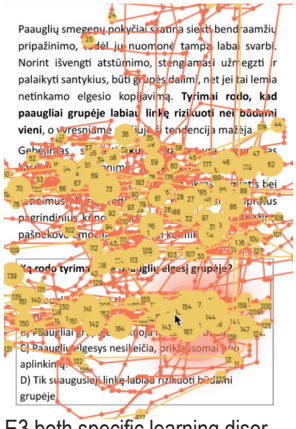
Highlighted Text with Retention Question



E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

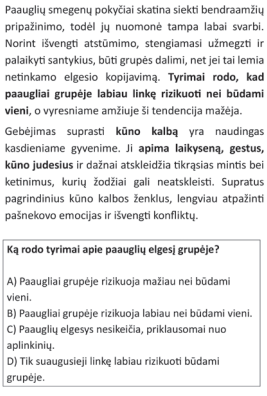


E2 was diagnosed with specific learning disorders (dyslexia)



E3 both specific learning disorders (reading and writing) and an attention disorder.

Neurotypical (T)



Example of the excercise

Note. The text: "Brain changes during adolescence motivate young people to seek peer approval, making their peers' opinions very important. To avoid rejection, they strive to form and maintain relationships, be part of a group, even if that means copying inappropriate behaviour. Studies show that adolescents are more likely to take risks in groups than alone, and this tendency decreases with age. The ability to understand body language – posture, gestures, and movements – is valuable in daily life. It can reveal intentions that words may not express. Recognizing these cues helps to understand others' emotions and avoid conflicts." Question and answer options: "What do studies reveal about adolescent behaviour in groups? A) Adolescents take fewer risks in groups than when alone. B) Adolescents take more risks in groups than when alone. C) Adolescent behaviour remains the same regardless of others. D) Only adults are more likely to take risks in groups."

Figure 5 presents scanpaths from the highlighted-text condition, where key segments were bolded to visually signal important content. E1's scanpath was erratic, moving in zig-zag patterns and shifting top-to-bottom and right-to-left. Numerous long saccades and regressions occurred, including returns to non-highlighted areas. E2 also exhibited zig-zag eye movements but showed clearer focus on highlighted parts. A direct scanpath from the question to the first bolded segment suggests successful use of visual cues and reduced cognitive load during reading. E3's scanpath was dense and disorganized. Many fixations clustered on the second highlighted part, although the correct answer was in the first (author's note: however, the question was answered correctly). T's scanpath was systematic, with many fixations directly on highlighted words, followed by a brief scan of the question and a chosen answer. This pattern suggests selective attention to critical content and effective use of signaling to reduce cognitive load. Overall, highlighting acted as a visual anchor for students with learning difficulties, helping reduce – though not entirely eliminate – their disorganized search behaviour seen in previous conditions.

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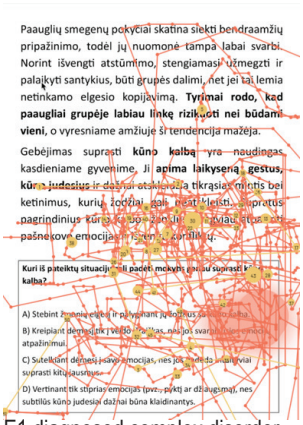
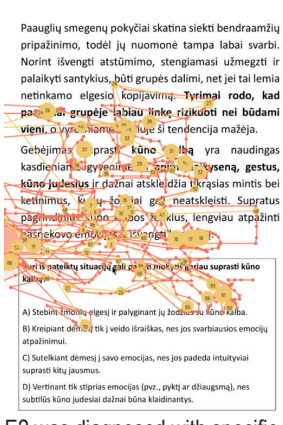
Figure 6

Highlighted Text With Transfer Question

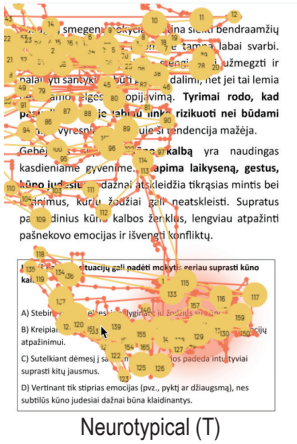


E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

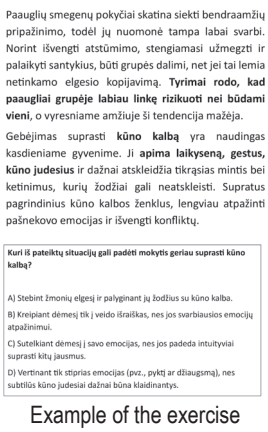


E2 was diagnosed with specific learning disorders (dyslexia)

E3 both specific learning disorders (reading and writing) and an attention disorder.



Neurotypical (T)



Example of the exercise

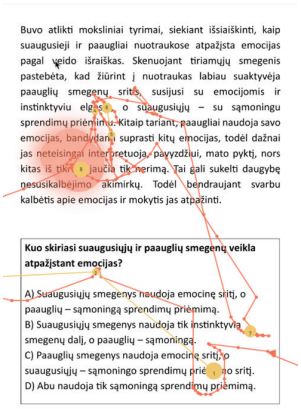
Note. Only question and answer options have changed: "Which situation could help someone learn to better understand body language? A) Observing people's behaviour and comparing it with their words. B) Focusing only on facial expressions, since they are key to emotion recognition.C) Paying attention to one's own emotions to intuitively understand others. D) Only interpreting strong emotions like anger or joy, since subtle cues can be misleading."

Figure 6 shows the scanpath in the highlighted-text condition with a transfer question. E1's scanpath remained highly disorganized and inefficient. While some fixations clustered on highlighted parts, fixation durations were short (no large dots visible), and frequent saccades moved between the question and unrelated text areas. These long, irregular saccades suggest reactive, not strategic, visual search. E2 showed more and longer fixations than E1, particularly around highlighted text. Moderate regressions and shorter saccades suggest re-reading to build inferences. Despite dyslexia, E2 used visual cues strategically, reducing search effort and supporting integrative processing. E3's scanpath showed partial guidance by the highlighted text, but also

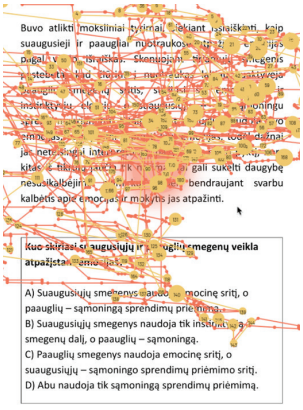
substantial disorganization. Fixations clustered in the question area, yet many saccades led to unrelated or empty regions. Highlighting drew attention but did not consistently support inference generation. In contrast, the student T displayed a clear reading sequence and focused fixations on emphasized content. T also had the longest fixation durations, proportionally distributed across the learning material.

Figure 7

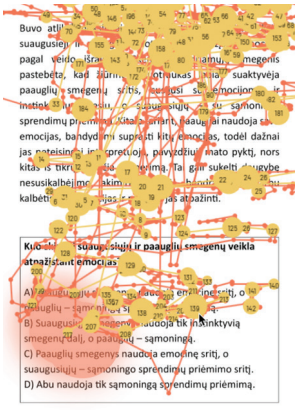
Control Text Without Any Additional Enhancing Elements With Retention Question



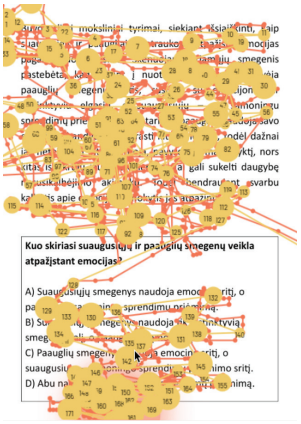
E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder



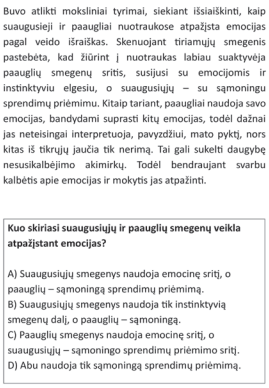
E2 was diagnosed with specific learning disorders (dyslexia)



E3 both specific learning disorders (reading and writing) and an attention disorder.



Neurotypical (T)



Example of the exercise

Note. "Scientific studies have explored how adults and adolescents recognize emotions from facial expressions. Brain scans revealed that adolescents activate regions associated with emotions and instinctive behavior, while adults engage areas linked to conscious decision-making. In other words, adolescents interpret others' emotions based on their own feelings, often misjudging them—for example, seeing anger where there is actually only anxiety. This can lead to miscommunication. That's why it is important to talk about emotions and learn to recognize them." Question and answer options: "How does brain activity differ between adults and adolescents when recognizing emotions? A) Adults use emotional brain areas; adolescents use decision-making areas. B) Adults rely on instinctive brain parts; adolescents rely on conscious thought. C) Adolescents use emotional brain areas; adults use decision-making regions. D) Both rely solely on conscious decision-making."

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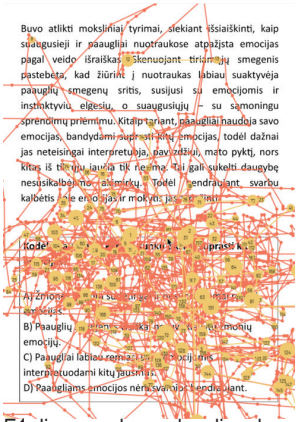
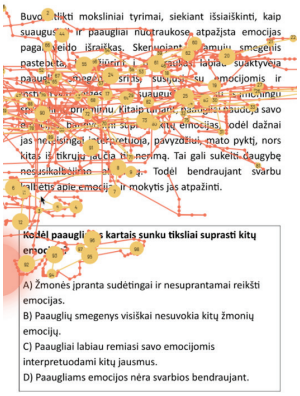
Figure 7 presents the scanpath from the control condition, where only plain text was provided with a recall question below. This served as a baseline for comparing reading strategies. E1's scanpath was highly scattered, with few short fixations and long saccades across the text and question area. E2 showed a relatively linear, methodical reading pattern not observed in previous conditions. Fixations were moderately dense, spread across the text, with short, local regressions typical of dyslexic reading. Saccades were short, and the gaze moved to the question after reading nearly the entire text. A single revisit (fixation number 149) suggests confident recall from working memory. E3's scanpath showed longer fixation durations clustered near the question and upper-middle text. Reading likely started mid-text, and transitions between clusters were poorly aligned with content relevance. While the question was visited multiple times, return paths lacked precision, indicating ineffective navigation and integration. T demonstrated a structured, low-effort reading pattern, with consistent top-to-bottom scanning and minimal regressions. Uniform fixation sizes suggest fluent decoding and low cognitive load. No regressions occurred after reading the question, indicating high recall accuracy.

Figure 8

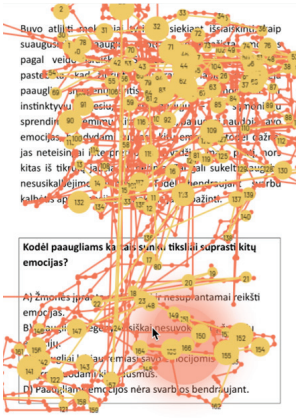
Control Text Without Any Additional Enhancing Elements with Retention Question



E1 diagnosed complex disorder involving specific learning disorders (reading and writing) and an attention disorder

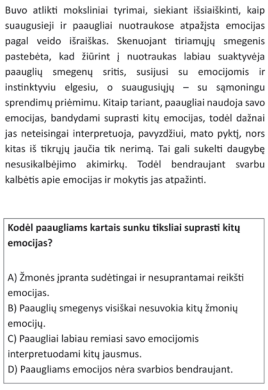


E2 was diagnosed with specific learning disorders (dyslexia)



E3 both specific learning disorders (reading and writing) and an attention disorder.

Neurotypical (T)



Example of the exercise

Note. Only question and answer options have changed: "Why is it sometimes difficult for adolescents to accurately recognize others' emotions? A) People express emotions in complex and unclear ways. B) Adolescents' brains cannot comprehend others' emotions. C) Adolescents rely more on their own emotions when interpreting others' feelings. D) Emotions are not important for adolescents in communication."

Figure 8 presents the scanpath from the control condition with a transfer question. E1's scanpath was extremely chaotic, with short, dense fixations concentrated near the lower text and question area. Saccades were long and multidirectional. Although the question attracted repeated attention, regressions to the text were unfocused and not task-driven. E2 showed sustained effort with a relatively linear reading pattern. After reading the question, E2 attempted to return to the relevant text areas, but the paths lacked precision. E3 reread the same text shortly after answering the recall question. Fixations were evenly distributed across the text and question area. Vertical saccades between both zones indicated a bidirectional search strategy. T briefly scanned the text, then focused almost entirely on the question area. Fixations were uniform in duration, and linear saccades suggested quick scanning of answer options. This focused gaze pattern reflects effective integration of information from working memory.

Discussion

This study examined how students with specific learning and attention disorders engage with science texts presented under different instructional enhancement conditions using eye-tracking data. The scanpath analysis uncovered distinct differences in reading strategies between neurodivergent (E1, E2, E3) and neurotypical student (T), as well as important insights into how instructional enhancements – such as highlighting and visual cues – modulate cognitive load and support reading strategies.

Participants diagnosed with both reading-writing disorders and attention deficits (E1 and E3) consistently exhibited fragmented, irregular scanpaths across all conditions, characterized by long, disorganized saccades and frequent regressions. These patterns suggest difficulty in sustaining attention and integrating information during reading, particularly under high cognitive load. Such findings align with Nagarajan et al. (2023) who emphasized that impaired executive function in readers with attentional disorders leads to disrupted scanpath and diminished inferential reasoning. E1's behaviour, especially in control, picture and infographic tasks, showed significant attentional capture by irrelevant elements (e.g., white space, decorative visuals), reflecting heightened vulnerability to extraneous cognitive load (Sweller, 2024).

In contrast, E2, diagnosed with specific learning disorders (dyslexia), displayed more focused, linear reading patterns. While decoding difficulties were evident in the form of short, frequent regression, E2 engaged with the tasks in a methodical way, particularly when visual cues (highlighted text) or only plain text were provided. These findings suggest that students with dyslexia may benefit from enhanced instructional scaffolding that reduces visual search demands and narrows attentional focus to key information (Parshina et al., 2022). In the absence of such scaffolds, E1's and E3's reading became less efficient, although student E2's reading pattern was the most organised in the plain text condition.

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Highlighted text consistently emerged as the most beneficial support for both E2 and E3. The visual signaling reduced wandering gaze behaviour and supported more accurate task-related regressions – in line with the signaling principle from multimedia learning theory (Mayer, 2024). E3, despite attentional impairments, exhibited notably improved fixation patterns when highlights were present, indicating that visual salience can partially offset deficits in top-down control (Coskun & Cagiltay, 2022). However, infographics and decorative pictures introduced mixed effects: while they did not distract the neurotypical student's visual attention, these visual elements distracted neurodivergent students and introduced extraneous load (Ma et al., 2022).

Neurotypical performance across all conditions was marked by short fixation durations, minimal regressions, and strategic re-reading. This participant consistently re-engaged only the relevant parts of the text post-question, exemplifying adaptive reading and comprehension strategies (Richter & Scheiter, 2019). The comparative efficiency of neurotypical scanpath highlights the gap in visual self-regulation skills among students with learning difficulties and underscores the need for educational design to mitigate this disparity.

Overall, this study reinforces the value of eye-tracking for diagnosing cognitive challenges and supports the integration of signaling and visual minimization strategies in science education for students with reading and attention disorders. Future research should explore adaptive learning environments that respond dynamically to students' visual behaviour, promoting more equitable access to scientific content and deeper learning.

Conclusions and Implications

This study looked into how students with specific learning and attention disorders (dyslexia and attention deficit, ADHD) process science texts under different instructional conditions, with a focus on seductive details and visual enhancements. Eye-tracking analysis revealed that neurodivergent students exhibited more disorganized scanpaths, longer saccades, and frequent regressions compared to the neurotypical student. Students with both dyslexia and attention deficits showed the most fragmented reading behaviour, while the student with dyslexia alone demonstrated more structured gaze patterns, especially in the plain and highlighted text conditions.

Seductive details, such as decorative images, consistently distracted neurodivergent students and increased extraneous cognitive load. These visuals drew attention away from the main text, particularly during tasks requiring inference. In contrast, highlighted text supported more focused reading and task-relevant regressions, though it did not entirely eliminate disorganized search behaviour.

The results support the use of signaling and visual simplification in science education for students with cognitive difficulties. Eye-tracking proved to be an effective method for revealing how these learners engage with texts. Future instructional designs should avoid unnecessary visual stimuli and emphasize clarity and relevance to better support reading comprehension and reduce cognitive strain.

This case study demonstrated that instructional design elements – such as text highlighting and decorative images – affect students with learning and attention disorders (dyslexia and attention deficit or ADHD) differently than neurotypical student.

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Eye-tracking data revealed that seductive details, including irrelevant images, frequently disrupted attention and increased cognitive load for neurodivergent students, while neurotypical students remained unaffected. In contrast, visual signaling through text highlighting partially supported more focused reading and helped guide attention toward relevant information. However, these supports did not fully compensate for disorganized scanpaths in students with combined attention and learning difficulties. These findings highlight the importance of minimizing unnecessary visual complexity and prioritizing clarity and relevance in instructional materials for cognitively vulnerable learners. Practically, the results suggest that science education content should avoid seductive details and instead incorporate targeted visual scaffolds that reduce search effort and cognitive strain. More broadly, this research supports principles of Universal Design for Learning (UDL) and demonstrates the value of eye-tracking as a tool to inform adaptive educational interventions. Future digital learning environments should aim to detect and respond to learners' attentional patterns in real time, promoting equitable access to academic content for all students.

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